BEDROCK GEOLOGY

OF

ANTARCTICA

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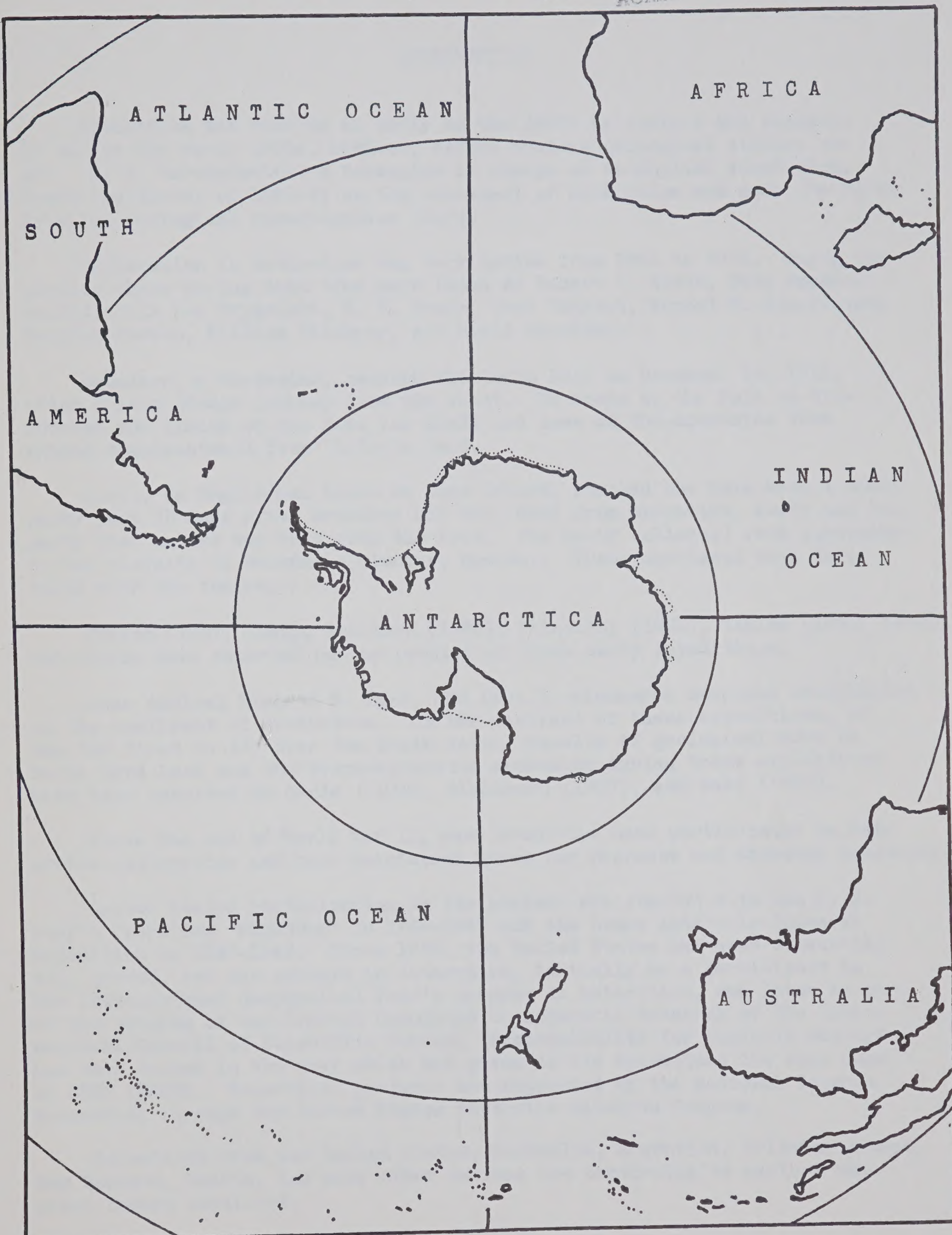
ATLANTIC OCEAN
AFRICA
SOUTH
AMERICA
INDIAN
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ANTARCTICA
PACIFIC OCEAN
AUSTRALIA

INTRODUCTION

Antarctica was visited as early as the 1820s by sealers and whalers. It was in the early 1900s, however, before serious geological studies began. C. E. Borchgrevink, a Norwegian in charge of an English expedition, spent the winter of 1898-99 on the continent of Antarctica and made the first detailed geological investigation there.

Exploration in Antarctica was very active from 1901 to 1914. Among the parties there during that time were those of Robert F. Scott, Otto Nordenskjold, Erik von Drygalski, W. S. Bruce, Jean Charcot, Ernest H. Shackleton, Douglas Mawson, William Filchner, and Roald Amundsen.

Amundsen, a Norwegian, reached the South Pole on December 14, 1911, after a long sledge journey from the coast. En route to the Pole he discovered the limits of the Ross Ice Shelf and some of the mountains that extend southeastward from Victoria Land.

Scott, an Englishman based at Ross Island, reached the Pole with a small party just 35 days after Amundsen did but, weak from privation, Scott and his party died on the way back from the Pole. The party collected rock specimens in the vicinity of Beardmore Glacier, however. These specimens were later found with the bodies.

Ferrar (1907, 1925), Reinisch (1906), Priestley (1923), Taylor (1922, 1930), and others have reported on the results of those early expeditions.

Rear Admiral Richard E. Byrd, USN (Ret.), pioneered American expeditions to the continent of Antarctica. On the earliest of these expeditions, he was the first to fly over the South Pole. Results of geological work in Marie Byrd Land and the trans-antarctic mountains during these expeditions have been reported by Gould (1935), Blackburn (1937), and Wade (1937).

Since the end of World War II, many countries have participated in Antarctic exploration and have maintained bases for oversnow and airborne traverses.

United States participation in the postwar era started with the U. S. Navy's Operation "Highjump" in 1946-1947 and the Ronne Antarctic Research Expedition in 1947-1948. Since 1955, the United States has been conducting sea, ground, and air surveys in Antarctica, initially as a participant in the International Geophysical Year's program in Antarctica, and later as part of the program of the Special Committee on Antarctic Research of the International Council of Scientific Unions. Responsibility for logistic support has been vested in the Navy which has given to its operations the code name of DEEP FREEZE. Scientific projects are supported by the National Science Foundation through the United States Antarctic Research Program.

Scientists from the United States, Australia, Argentina, Britain, France, New Zealand, Russia, and many other nations are continuing to explore the great frozen continent.

Recent reports on the geology of Antarctica are numerous. There is space here, however, to mention only a few. Davies (1956), Fairbridge (1952), Hamilton (1960), Lebedev (1959), and Stewart (1956) discuss the continent as a whole, whereas Adie (1954, 1955, 1957), Bentley, Crary, Ostenso, and Thiel (1960), Nichols (1955, 1960), Passel (1945), and Tyrell (1930, 1945) discuss parts of the geology of the folded belt and volcanic island archipelago area, generally called West Antarctica. Augenbaugh (1958), Crohn (1959), Hamilton and Hayes (1960), Long (1959), Pewe (1959), Weihaupt (1960), and others discuss the geology of parts of the shield area, generally called East Antarctica.

The following summary of the bedrock geology is drawn from a review of the published reports mentioned above, and from other surveys and personal reports from geologists who are currently engaged in Antarctic research.

Most writers have divided Antarctica's 5.5 million square miles into two sections. The area between 0 and 180 degrees West longitude, south of South America and the Pacific Ocean, is known as West Antarctica and the area between 0 and 180 degrees East longitude, south of Australia, the Indian Ocean, and Africa, is known as East Antarctica. In this report, the continent is described as a folded belt with volcanic island archipelagos which is mainly in West Antarctica and a shield area which is mainly in East Antarctica.

FOLDED BELT AND VOLCANIC ISLAND ARCHIPELAGO

The folded belt and volcanic island archipelagos include the Scotia Island Arc, Palmer Peninsula, "Ellsworth Land", Marie Byrd Land, and the volcanic islands on the west side of the Ross Sea (Figure 1).

[Figure 1, "Approximate Areas of Exposed Bedrock in Antarctica", appears as a fold map at the end of the publication.]

In this area, mountains jut through the ice to heights as great as 14,000 feet above sea level. The surface of the ice cap in most of the interior ranges from 5,000 to 8,000 feet in altitude. The bedrock surface in part of this area (Marie Byrd Land) is believed to be below sea level and under an ice cap as much as 14,000 feet thick.

The folded belt and volcanic island archipelago consist of igneous, metamorphic, and sedimentary rocks believed to be structurally related to the Andes of South America because major folds can be traced southward from the Andes through the Scotia Arc to the Palmer Peninsula.

SCOTIA ISLAND ARC AND PALMER PENINSULA

The Scotia Island Arc and Palmer Peninsula lie south of South America between 20 and 80 degrees West longitude.

The South Shetland, the South Orkney, and the South Sandwich Islands, parts of the Scotia Arc, are composed of folded metamorphic, plutonic, volcanic and sedimentary rocks. The metamorphic rocks in the arc are intruded by plutonic rocks, and are flanked on the west by volcanic rocks and on the east by sedimentary rocks of Mesozoic and Cenozoic age.[1] In the South Orkney Islands, however, older sedimentary rocks have been found such as shale and graywacke of Ordovician age and limestone of possible Cambrian age.

Bedrock in the Palmer Peninsula is similar to that in the Scotia Arc. It consists of metamorphic and igneous rocks that are overlain and flanked by folded sedimentary and volcanic rocks.

The basement metamorphic complex of the Palmer Peninsula is made up of varieties of mica and hornblende schists and hornblende and granite gneisses of probable Precambrian or early Paleozoic age. These rocks crop out on the Fallieres Coast of southwestern Palmer Peninsula and occur in debris from the nunatAks of northwestern Alexander I Island. Foliation of the schists and gneisses generally strikes northeastward but is varied locally, owing to intrusions by igneous rocks.

Boulders of hornblende schist and gneiss that match rocks of the Fallieres Coast are found in the northeastern portion of the Palmer Peninsula, James Ross Island, and the Seal Nunataks. However, these boulders may have been moved northward at a time when the ice was 1,500 feet higher than at present.

The metamorphic rocks are intruded by "coarse pink granite" and "white granite" along the Fallieres Coast; the "pink granite" is the more widespread of the two rock types, and in some places it contains inclusions of altered andesite. These granites are tentatively considered to be early Paleozoic in age.

Metamorphic and sedimentary rocks of late Paleozoic age, called the Trinity Peninsula series, crop out on the east and west coasts of Palmer Peninsula as far south as 75 degrees South latitude. Rocks in this group are similar to rocks in some islands of the Scotia Arc. The sedimentary rocks have undergone metamorphism within thermal aureoles near intrusive rocks of early Tertiary age. The series includes graywacke, shale, slate, various types of hornfels and micaceous and shistose rocks. Sulfide minerals, tourmaline, and actinolite occur in rocks near diorite and granodiorite intrusives.

Folded rocks of Jurassic age consisting of slate, sandstone, and conglomerate crop out on the eastern side of Palmer Peninsula. Similar rocks,

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1 Geologic ages referred to in this report are in accordance with the time divisions used by the U. S. Geological Survey. A table showing these ages appears following the Glossary.

including limestone, occur on the east side of Alexander I Island. All of the Jurassic rocks are intruded by volcanic rocks.

Rocks containing fossils of Cretaceous age crop out on islands at the northeastern end of Palmer Peninsula. These rocks, called the Snow Hill group, are conglomerate, fossiliferous sandstone, and tuff.

Unconformably overlying the Cretaceous rocks is the Seymour Island group, which consists of continental deposits of sandstone, conglomerate, and tuff of Eocene and Oligocene age and marine calcareous sand of Oligocene and Miocene age.

Probably the youngest sedimentary rocks in the Palmer Peninsula area are the "Pecten" beds of late Pliocene and early Pleistocene age on Cockburn Island. These beds consist of basalt tuff that is overlain by ash-cemented basal debris.

The youngest unconsolidated material in the Palmer Peninsula area may be the "Thoracia clays" of late Pleistocene (?) or early Recent (?) age which are found north of James Ross Island. These sediments contain fossils of modern species.

Batholiths of granite to gabbro composition, possibly of Late Cretaceous or early Tertiary age, form part of the Palmer Peninsula and the larger part of the Palmer Archipelago, the Biscoe Islands, and the western part of the South Shetland Islands. These batholiths have intruded the rocks of the Trinity Peninsula Series of late Paleozoic age and rhyolite-andesite rocks of Jurassic age. At the widest part of the Palmer Peninsula, at 70 degrees South latitude, the batholiths underlie a mountain chain that is estimated to be 12,000 feet high and which extends southward nearly to 76 degrees South latitude.

MARIE BYRD LAND AND "ELLSWORTH LAND"

The fold belts of the Palmer Peninsula have been thought to fan out southwestward into "Ellsworth Land", possibly through the Ellsworth Mountains (Figure 2) and on into the Edsel Ford Ranges to the northwest (Figure 1). However, the trend of the Sentinel Range is northwest, not south or southwest as previously supposed, so the folds of the Palmer Peninsula may not extend to the Sentinels - or if they do, they change direction or curve sharply beneath the ice of "Ellsworth Land."

The rocks from the Marie Byrd Land - "Ellsworth Land" area appear to be similar to those of Palmer Peninsula. Folded low-grade metamorphic rocks have been found in part of the Sentinal Range; however, as only a small area was examined, other rock types may occur there.

Rocks in the Edsel Ford Ranges of Marie Byrd Land are sandstone, shale, quartzite, and slate about 15,000 feet thick that are folded and intruded by

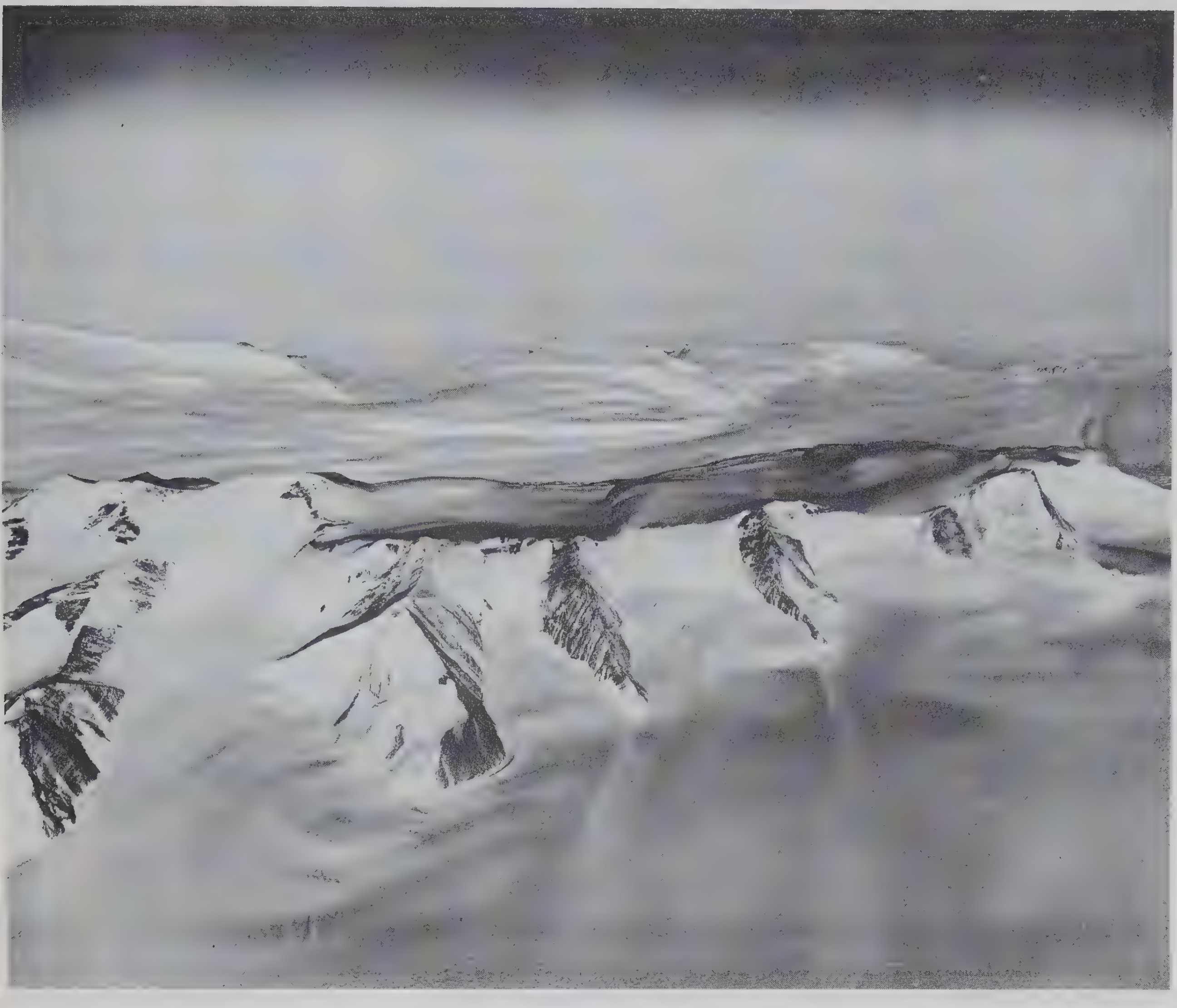

Figure 2: North end of the Sentinel Range in the Ellsworth Mountains, Antarctica.

granite. The beds are almost vertical and strike northwest in the south but north-northeast in the north. The eastern part of these ranges is composed partly of fine-grained, contact-metamorphosed graywacke that is intruded by hornblende granite, probably of batholithic proportions, and by aplite and mafic dikes.[2] (Figure 3). Veinlets of copper minerals occur in the contact zones.

The north-central part of Marie Byrd Land, east of the Edsel Ford Ranges,

2 E. L. Boudette, 1960, written communication.

Figure 3: Exposure of pinkish-brown, coarsegrained hornblende granite in the Clark Mountain group of the eastern Edsel Ford Ranges showing jointing. Relief is about 700 feet.

may be the site of a volcanic island archipelago (Figure 4). Evidence for this hypothesis is that the bedrock is considerably below sea level between the Ames, Executive Committee, and Hal Flood Ranges, and the Crary Mountains. In the Crary Mountains and at Toney Mountain, the bedrock is composed of basaltic rocks and volcanic conglomerates that have been cut by minor intrusives[3]. East of Mt. Petras, folded rhyolite and pyroclastic rocks are exposed and five miles west of these exposures, diorite is unconformably overlain by volcanic conglomerate and flows.[4]

The Thurston Peninsula area, over 300 miles northeast of the Crary Mountains, contains a few exposures of granite, schist, granite gneiss, and slightly metamorphosed folded graywacke, sandstone, and shale. The bedding and foliation strike northeast and dip steeply southeast.[5] Similar

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3 Ibid.

4 Ibid.

5 H. A. Hubbard, 1960, written communication.

Figure 4: Interbedded columnar-jointed basalt flows and mafic pyroclastic rocks exposed on the northeast side of a mountain group in the western part of the Kohler Range, Marie Byrd Land, Antarctica. Strato-volcano form with little erosional destruction and probable northeast-facing fault scarp is shown.

rocks may lie to the east along the Bellingshausen Sea coast, but exploration is just beginning along the coasts of Marie Byrd Land, the Thurston Peninsula, and the Bellingshausen Sea, so other rock types may be found in the general area.

VOLCANIC ISLANDS ON WEST SIDE OF THE ROSS SEA

Many volcanic islands of Recent (?) age exist on the west side of the Ross Sea and in the adjacent South Pacific Ocean. Ross Island, one of the most prominent of these volcanic islands, is composed of Mt. Erebus (Figure 5), Mt. Terror, Mt. Terra Nova, and several smaller cones. Mt. Erebus, the only known recently active volcano in Antarctica, is made up of volcanic rocks of various compositions. The older rocks on Mt. Erebus are trachyte and basalt and the younger rocks around the cone are kenyte-type lava.

Other volcanos in the Ross Sea-Cape Adare vicinity are Scott Island, the Balleny Islands, and several small islands near the Victoria Land Coast.

Figure 5: Cone of Mt. Erebus on Ross Island; the only known recently active volcano in Antarctica.

Mt. Discovery and many small cones and flows on the coast of Victoria Land are composed of leucite basalt, olivine basalt, and andesite.

THE SHIELD AREA

The shield area of Antarctica, or that part known as East Antarctica, is generally considered to be a shield of igneous and metamorphic rocks that are overlain by nearly flat lying sedimentary rocks. It encompasses the "trans-antarctic mountain belt", Wilkes Land, Enderby Land, Queen Maud Land, and Coats Land. High mountains exist along the trans-antarctic mountain belt, some as much as 15,000 feet above sea level. Mountains 9,000 to 12,000 feet in altitude are in Enderby Land and Queen Maud Land. However, the vast interior of the shield area of Antarctica, as far as is known, is a relatively featureless high ice plateau of 10,000 to 14,000 feet altitude. This plateau ice is as much as 10,000 feet thick in some places. Bedrock may be near or below sea level beneath the plateau ice cap in the interior, especially in Wilkes Land.

THE TRANS-ANTARCTIC MOUNTAIN BELT

A long belt of almost continuous mountain ranges extends across Antarctica, along one side of the shield area from Cape Adare on the Ross Sea to Coats Land on the Weddell Sea. This belt is called the "trans-antarctic mountain belt" in this report, as suggested by Warren Hamilton.[6] Relief in this mountain belt ranges from 3,000 to 12,000 feet or more, and summits are as high as 15,000 feet above sea level. The highest peak known in the trans-antarctic mountains is the 15,000-foot peak of Mt. Markham in the Queen Alexandria Range.

The geology of the trans-antarctic mountains is best known along the western side of the Ross Sea between the Horlick Mountains (near 85 degrees South latitude) and Cape Adare (71 degrees South latitude). In this area, the mountain belt forms a prominent chain approximately 1,500 miles long and as much as 125 miles wide. The basement rocks in this part of the belt are mica gneiss, mica schist, fine-grained graywacke, and marble that are intruded by large bodies of granite, diorite, monzonite, and quartz monzonite. The age of these crystalline rocks ranges from possible Precambrian to known Cambrian; the latter demonstrated by fossil evidence. Hornblende diorite and quartz latite dikes are commonly found in the contact zones between the large intrusive bodies and their metamorphic host rocks.

During the early part of the Paleozoic era, the rocks of the basement complex were broken by faults, uplifted in an episode of mountain building, and subaerially weathered and eroded. This period of mountain building or orogeny was followed by a general subsidence and deposition of sedimentary rocks beginning in Devonian time and probably extending into Jurassic time. These sedimentary rocks are, in part, of marine origin, but coal measures and related rocks are found in them that are of terrestrial origin. The upper part of the sedimentary rock sequence has been popularized in the literature as the Beacon sandstone. This terminology is modified to the Beacon group and used in this paper. The Beacon group is known to be 5,000 feet thick at Mt. Lister (78 degrees South latitude, 162 degrees East longitude) and 3,000 feet thick in the Taylor Valley area (Figures 6 and 7). In these areas, the Beacon group consists of fine- to coarse-grained, cross-bedded

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6 Informal communication.

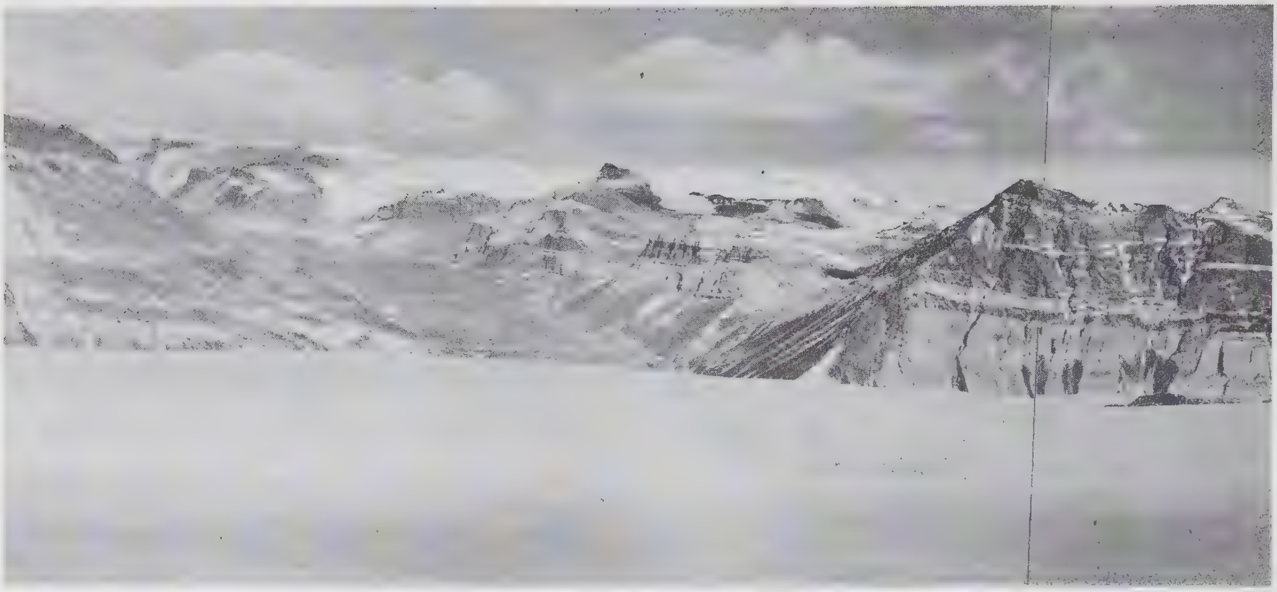

Figure 6: Relatively flat-lying sandstone of the Beacon group intruded by

arkose, quartz sandstone, quartz pebble conglomerate, graywacke, siltstone, and limestone. Beds of coal a few feet thick occur stratigraphically high in the group. J. J. Mulligan[7] found bedding in the Beacon group dipping as much as five degrees West near Mt. Gran (approximately 50 miles north of the Taylor Valley), but generally the bedding in the Beacon group is characteristically flat.

The basement complex and sedimentary rocks in Victoria Land (Figure 6) are intruded by quartz diabase sills and dikes. The total thickness of the sills is probably more than 4,000 feet in some areas. Some sills as much as 1,300 feet thick intrude rocks 500 to 1,500 feet stratigraphically below the Beacon group. Following the emplacement of the quartz diorite bodies, normal faulting with displacements as much as 1,000 feet cut the rocks of the mountain belt. The youngest rocks known in the Victoria Land area are mafic (basaltic) volcanic rocks such as those underlying Mt. Discovery about 60 miles southeast of the Taylor Valley. These volcanic rocks are very likely related in age and lithology to those known on Ross Island about 40 miles to the east of the Taylor Valley. The Admiralty Range, part of the trans-antarctic mountains in Victoria Land, is underlain by folded, low-grade metamorphic rocks consisting predominantly of slates and coarse-grained graywacke. Both rock types are cut by numerous quartz veins. This rock sequence, in which fold axes trend approximately north-south, is, lithologically, a marked contrast to the geology known to the south along the mountain belt. Very little is presently known about the relationship of these two contrasting lithologic terranes.

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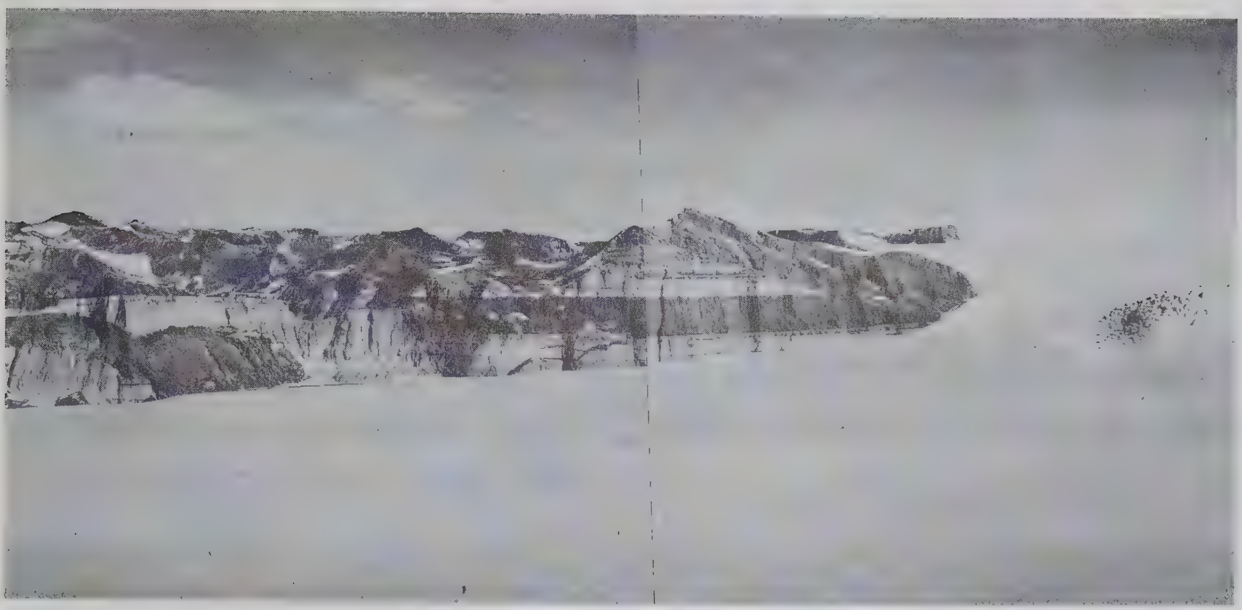
7 1960, personal communication.



diabase sills near the head of the Taylor Glacier, victoria Land, Antarctica.

During the 1959-60 austral summer, a mountain range was discovered just north of the Prince Albert Mountains and south of Rennick Bay (71 to 73 degrees South latitude, 160 to 162 degrees East longitude). These mountains appear to be underlain by sedimentary, metamorphic, and igneous rocks.[8] Specimens which the writer has identified as mica schist and granitic pegmatite are available from only one mountain. These rocks are similar to those known in the Prince Albert Mountains and the dry valley area to the south.

Eastward from the Horlick Mountains, the Dufek Massif and the Pensacola Mountains are less well-known than the mountain belt in the Ross Sea region. In the Dufek Massif (approximately 83 degrees South latitude, 50 to 54 degrees West longitude), a crystalline statiform complex is exposed which is predominantly norite. Nearly horizontal layers characterize the norite, which has been intruded by pegmatite and felsite dikes. Copper minerals, magnetite, and chromite are found both in glacial erratics and in place. It is significant that boulders of sedimentary and metamorphic rocks, as well as igneous rock types other than norite, are also found in the moraines in the area.

Farther to the northeastward along the trans-antarctic mountain belt, ranges such as the Theron Mountains (79 to 80 degrees South latitude, 24 to 30 degrees West longitude) and the Shackleton Range (80 to 81 degrees South latitude, 28 to 30 degrees West longitude) are underlain by schist and gneiss basement rocks of possible Precambrian to Cambrian (?) age which are unconformably overlain by essentially flat-lying sedimentary rocks. These sed-

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8 J. G. Weihaupt and Claude Lorius, 1960, oral communication.

Figure 7: A dry valley in Victoria Land west of McMurdo Sound; looking eastward. Mt. Erebus is on the horizon in the background. The light-colored rock capping the peaks is the Beacon group.

imentary rocks are probably Permian, as indicated by plant fossils contained in them. Coal of anthracite rank is found in the sedimentary rocks in the Theron Mountains. In the same area, the Whichaway Nunataks, south of the Shackleton Range, are underlain by sedimentary rocks which have been intruded by diabase. Apparently no basement crystalline rocks have been seen in this area, but it is likely that they underlie the sedimentary rocks as they do elsewhere in this lithologic setting in the trans-antarctic mountain belt.

WILKES LAND-ENDERBY LAND

In general, the geology of the coastal areas of Wilkes Land and Enderby Land is similar to that of the trans-antarctic mountain belt. The basement rocks, however, contain hypersthene granite in the Wilkes Land-Enderby Land area of the shield.

Basement rocks of granite and gneiss that crop out at Horn Bluff along the George V Coast at 150 degrees East longitude are overlain by 1,000 feet of sandstone that is similar to the Beacon group. This sandstone contains coal and carbonaceous shale and is intruded by thick diabase sills. Similar rocks crop out at Commonwealth Bay and Cape Margerie along the Adelie Coast near 142 degrees East longitude, with the exception that the sandstone is not reported at Cape Margerie.

Between 115 and 45 degrees East longitude, the coastal area consists of basement rock of probably Precambrian age that are in part overlain by sedimentary rocks of probable late Paleozoic age. The basement rocks are quartzite, quartz-feldspar-garnet gneiss, granite gneiss, and related gneisses, some containing hypersthene. Granitic gneiss grades locally into banded hybrid gneiss and migmatite. Pegmatites, quartz lenses, and bands or lenses of pyroxene, garnet, and magnetite are also abundant. Intruded into the other basement rocks are large bodies of hypersthene granite with pegmatite and aplite.

Sedimentary rocks of probable late Paleozoic age, faulted against the basement complex to the west, occur in an area of about 200 square miles in the Amery Locality at 70 degrees and 30 minutes South latitude and 68 degrees and 15 minutes East longitude. These rocks, estimated to be at least 1,000 feet thick, are a series of flat-lying arkosic sandstones and grits, locally crossbedded, with pebble beds and at least two coal seams about 8 inches thick. Pollen and spores contained in the coal have been found to be Permian in age; therefore it is believed that these sedimentary rocks are the equivalent of the Beacon group of the trans-antarctic mountains.

Mafic dikes as much as 50 feet wide and several miles long have been found in the Vestfold Hills. In the Prince Charles Mountains, the basement rocks have been intruded by basaltic dikes. Erratics of diabase and basalt occur in the vicinity of Ice Bay. The diabase is tentatively correlated with the diabase that intrudes the Beacon group in the trans-antarctic mountains; however, no dikes have been found in the sedimentary rocks in the Amery area.

The only volcanic rock known in the coastal area from George V Coast to Enderby Land is a volcanic plug of leucite basalt of Tertiary (?) age that has been reported near 90 degrees East longitude at the Gaussberg.

QUEEN MAUD LAND-COATS LAND

In the vicinity of the Princess Astrid Coast and Princess Martha Coast of Queen Maud Land, mountains are composed of a basement metamorphic complex, metasedimentary rocks and volcanic rocks. In this general area, the basement metamorphic complex consists of hornblende-biotite gneiss, garnetiferous gneiss, granite gneiss, hornblende schist, chlorite schist, minor migmatite, and quartzite. Folded slates and graywackes as much as 6,000 feet thick have been intruded by diabase sills as much as 1,800 feet thick. Sandstone resembling that of the Beacon group has been reported about 200 miles south of Maudheim.

Rocks dredged from the coast of Coats Land indicate the probable existence of a crystalline basement of Precambrian age, limestone of Cambrian age, and sandstone of the Beacon type. The sandstone may cap the flat-topped mountains that have been reported in Coats Land.

STRUCTURAL RELATIONSHIP OF THE FOLDED BELT AND VOLCANIC ISLAND ARCHIPELAGO AREA TO THE SHIELD AREA

The structural relationship of the folded belt and volcanic island archipelago to the shield has been discussed for many years. In the last two years, however, much has been learned of the bedrock surface beneath the ice between the Ross and the Weddell Seas.

A theory was postulated in the past that a great antarctic horst and an adjacent graben extended across southern Marie Byrd Land along the northern front of the trans-antarctic mountains from the Ross Sea to the Weddell Sea. The axis of this horst was thought to extend across the Pacific Ocean to Australia, where it joined the East Australian Horsts. Now, with new and more comprehensive data, some geologists doubt that a horst of such magnitude exists.

Probably during Precambrian and Cambrian time geosynclinal sedimentary rocks were folded, metamorphosed, and intruded by batholiths; in the late Paleozoic and Mesozoic eras more sedimentary rocks were deposited on top of the metamorphic and igneous rocks. Uplift and faulting of these rocks on the Ross Sea side of the shield during the Cenozoic era probably produced the long belt of trans-antarctic mountains seen today. Intense volcanic activity accompanied the faulting and resulted in a chain of volcanos which includes Mt. Erebus and the volcanos elsewhere along the western side of the Ross Sea.

A broad ice-filled channel has been postulated to connect the Ross and the Weddell Seas. However, seismic data gathered recently indicate that a ridge of bedrock probably exists under the ice between the Sentinal Range and the Horlick Mountains of the trans-antarctic mountain belt, precluding the existence of such a channel. Several nunataks have been found between these mountains, corroborating the theory of a connecting ridge. A deep ice-filled channel may extend, however, between the Bellingshausen and Ross Seas.

MINERAL AND FUEL RESOURCES

Little exploration and no exploitation of Antarctica's mineral and fuel resources have occurred to date. As far as the writer can determine, no mineral deposits have been found that compare with economic concentrations elsewhere on the earth. There are records of the discovery of some ore minerals. About 174 mineral species, subspecies, and varieties have been found in Antarctica; among these are atacamite, azurite, bornite, cassiterite, chalcopyrite, chromite, galena, gold, hematite, magnetite, malachite, molybdenite, monazite, sphalerite, and stibnite.

Coal of different grades, from lignite to anthracite, has been discovered in many places in the sandstones of the shield area. This fossil fuel has been found in thin beds within the Beacon group from the high mountains of Victoria Land southeastward to the Horlick Mountains and the Theron Mountains. Near the Beardmore Glacier, an 8-foot bed of coal has been found; however, in most places the coal is in seams a few inches to a foot or two thick. Sandstone similar to that of the Beacon group of Victoria Land contains some coal in the Amery Locality and at Horn Bluff on George V Coast.

GLOSSARY

actinolite	a light green to dark green mineral of the amphibole group; found in schists and contact rocks, also in veins and igneous rocks as an alteration product.
arkose	a fine to coarse-grained sedimentary rock consisting of more than 25 per cent feldspar.
atacamite	a green copper mineral found in the oxide zone of copper deposits.
graben	a block of rock longer than it is wide that has been dropped down by faulting, relative to blocks on either side.
hornfels	a fine-grained, non-schistose metamorphic rock resulting from contact metamorphism.
kenyte	an olivene-bearing crystalline volcanic rock.
latite	a volcanic rock; the extrusive equivalent of monzonite.
metasedimentary rock	partly metamorphosed sedimentary rock.
migmatite	composite rock of gneiss or schist that contains granitic material in thin but numerous layers.
norite	a plutonic igneous rock, a variety of gabbro.
nunatak	an isolated hill or peak that projects through the surface of a glacier.
pecten	a mobile pelecypod or clam found in shallow marine water.
pegmatite	coarse-grained dikes of igneous rock usually associated with a large mass of plutonic rock of smaller grain size.
shield	a continental block of the earth's crust, composed mostly of Precambrian rocks that have been relatively stable over a long period of time and has undergone only gentle warping.
thermal aureole	zone of heating surrounding an intrusion; the zone of contact effects, in part due to heat, surrounding an intrusion.

MAJOR STRATIGRAPHIC AND TIME DIVISIONS IN USE BY THE U. S. GEOLOGICAL SURVEY

Era	System or Period		Series or Epoch	Estimated ages of time boundaries in millions of years.
Cenozoic	Quaternary		Recent	
			Pleistocene	1
	Tertiary		Pliocene	10
			Miocene	25
			Oligocene	40
			Eocene	60
			Paleocene	
Mesozoic	Cretaceous		Upper (Late) Lower (Early)	125
	Jurassic		Upper (Late) Middle (Middle) Lower (Early)	150
	Triassic		Upper (Late) Middle (Middle) Lower (Early)	180
Paleozoic	Permian			205
	Carboniferous systems	Pennsylvanian	Upper (Late) Middle (Middle) Lower (Early)	
		Mississippian	Upper (Late) Lower (Early)	255
	Devonian		Upper (Late) Middle (Middle) Lower (Early)	315
	Silurian		Upper (Late) Middle (Middle) Lower (Early)	350
	Ordovician		Upper (Late) Middle (Middle) Lower (Early)	430
	Cambrian		Upper (Eate) Middle (Middle) Lower (Early)	510
Precambrian			Informal subdivisions such as upper, middle, and lower, or upper and lower, or younger and older may be used locally	> 3,000

Terms designating time are in parentheses. Informal time terms early, middle, and late may be used for the eras, and for periods where there is no formal subdivision into Early, Middle, and Late, and for epochs. Informal rock terms lower, middle, and upper may be used where there is no formal subdivision of a system or of a series.

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Figures 2, 5, 6, and 7 are Official United States Navy Photographs. Figures 3 and 4 were taken by E. L. Boudette of the U. S. Geological Survey.

The name "Ellsworth Land" has been used for that area previously known as Ellsworth Highland.

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APPROXIMATE AREAS OF EXPOSED BEDROCK IN ANTARCTICA

BEDROCK GEOLOGY OF ANTARCTICA

by Alfred R. Taylor

Figure 1

S — SEDIMENTARY ROCKS

MS — META - SEDIMENTARY ROCKS

MC — METAMORPHIC COMPLEX

IGN — INTRUSIVE ROCKS [Palmer Peninsula Area]

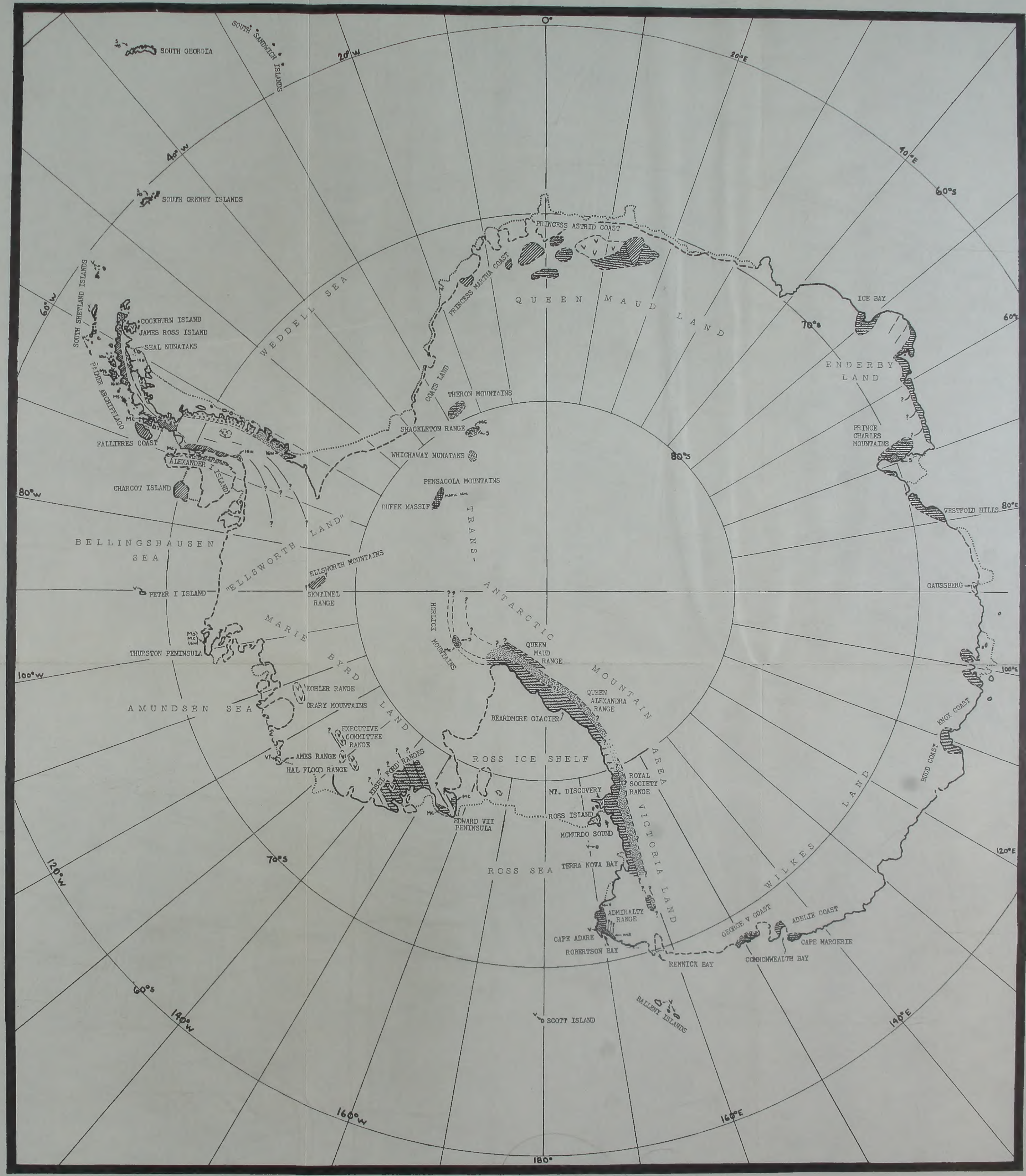
MAFIC IGN — MAFIC IGNEOUS INTRUSIVE ROCKS

V — VOLCANIC ROCKS

Probable Trend of Folds

0 — 600 NAUTICAL MILES

0 — 1000 KILOMETERS



After Davies, W. E., "Antarctic Stratigraphy and Structure", in Antarctica in the International Geophysical Year, Geophysical Monograph Number 1, American Geophysical Union, 1956, Figure 2. Revised by A. R. Taylor according to unpublished data furnished by E. L. Boudette and H. A. Hubbard, U. S. Geological Survey; Claude Lorius, Expeditions Polaires Francaises; J. J. Mulligan, U. S. Bureau of Mines; and J. G. Weihaupt, Geophysical and Polar Research Center, University of Wisconsin.

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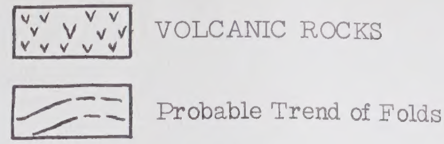

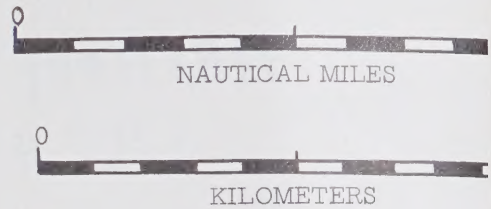

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